Mapping Faults With Lightning, Natural-Sourced Electromagnetics (NSEM)

Validating NSEM with 2-D Resistivity Imaging Profiling & Ground Penetrating Radar

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Project Background

This began as a validation study to determine whether known active growth faults in the Houston, Harris County area could be identified in the subsurface with NSEM 3-D resistivity data.

Once this objective was achieved the study expanded to document how stratigraphy could be identified and even mapped from NSEM data, similar to how 3-D seismic data is interpreted .

Additional validation studies have been documented to illustrate NSEM’s full potential for application to resource exploration. These can be found in the presentation titled:

“Lightning, A Shockingly Unconventional Way to Conduct Exploration.”

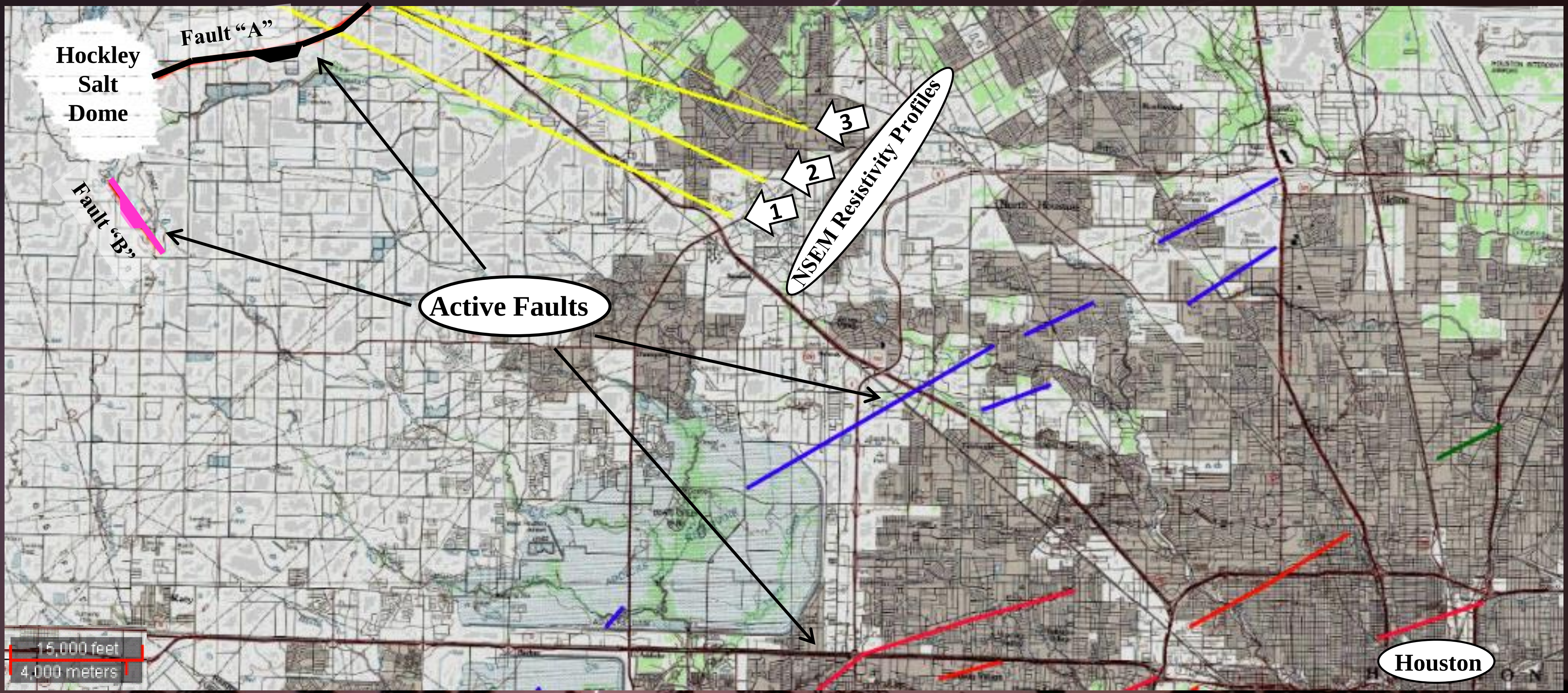
Active Faults in Houston Metropolitan Area

- There are approximately 300 active & potentially active normal faults in the Houston/Harris County, TX area. Many have a surface expression & can be identified by the property damage caused by displacement across these faults.

- Some of these faults have been further documented & mapped using near surface geophysical techniques such as resistivity imaging profiling, ground penetrating radar & seismic refraction.

- NSEM data was evaluated to demonstrate its ability to identify subsurface faulting & how it could be easily integrated with conventional near surface geophysical techniques to obtain a more complete geological understanding of the subsurface.

Houston/Harris County Area Active Faults



Fault Characteristics

- The predominantly south-dipping Houston area faults are believed to be listric growth faults having near surface fault plane dips of 60-75 degrees. Down-to-the-north antithetic faults are also present.

- Faults selected for this study were three radial faults associated with the Hockley Salt Dome, located approximately 35 mi. northwest of downtown Houston. Two of these are designated faults "A" & "B" on the previous slide and are down-to-the south and west respectively. A fourth fault located south of Tomball, TX was also evaluated with NSEM.

- NSEM data used in this study consisted of resistivity profiles derived from lightning strike data. Published maps of the fault locations & 2-D resistivity image profiles were used to tie the NSEM profiles to surface fault locations.

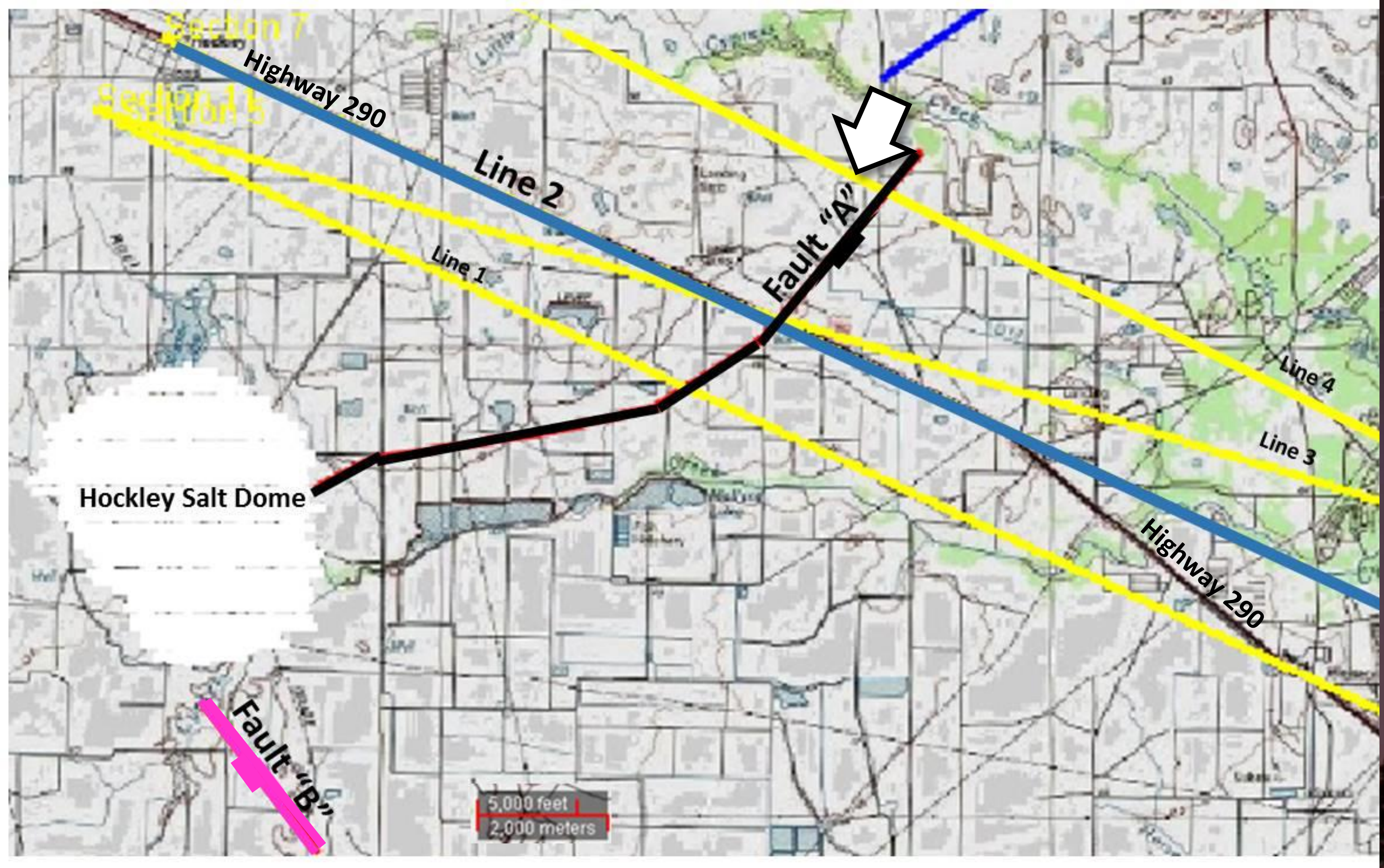
Data Integration

- A series of profiles (“Lines”) striking approximately perpendicular to the fault traces were extracted from the NSEM resistivity volume & the surface locations of the active faults were posted on each profile.

- The NSEM data is estimated to begin at 5,200’ to 5,600’ & is based on the estimated depth of lightning penetration derived from average cloud height, average peak charge of the area’s lightning strikes & an average velocity of 8,000’/sec to convert two-way resistivity times to approximate depth.

- Based on publications describing near & subsurface measurements of the area’s faults, potential subsurface fault matches to surface fault cuts were trigonometrically constrained by heave as a function of estimated fault angle versus depth relationships.

Hockley Radial Fault "A"

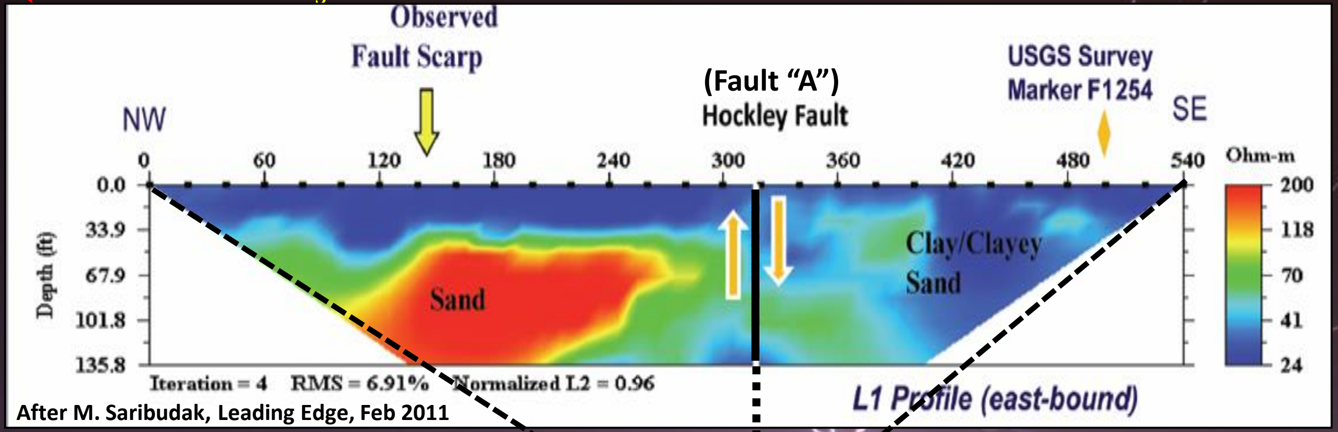


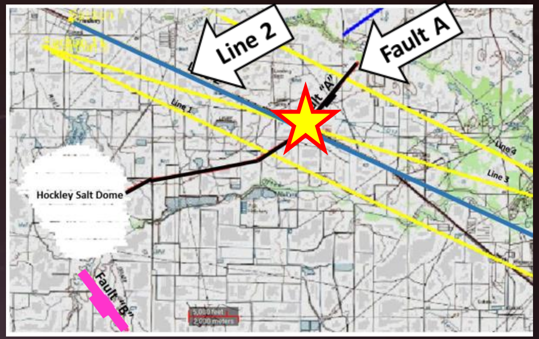
Resistivity profile "Line 2" displayed in next slide.

Hockley Fault "A"

See Lightning . . . DML . . . think DML & solutions

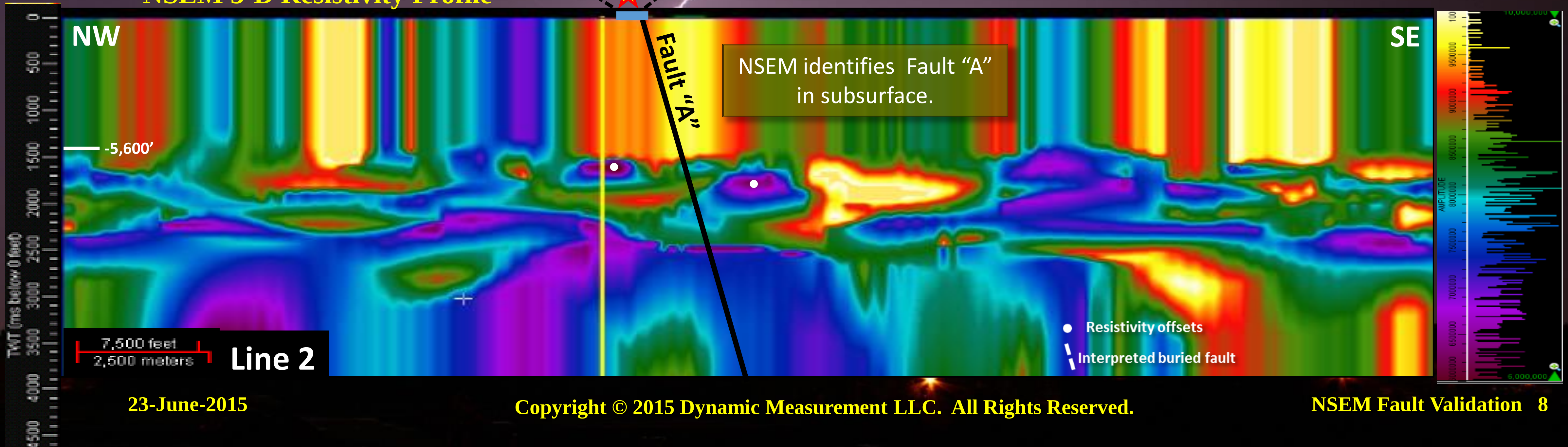
2-D Resistivity Profile





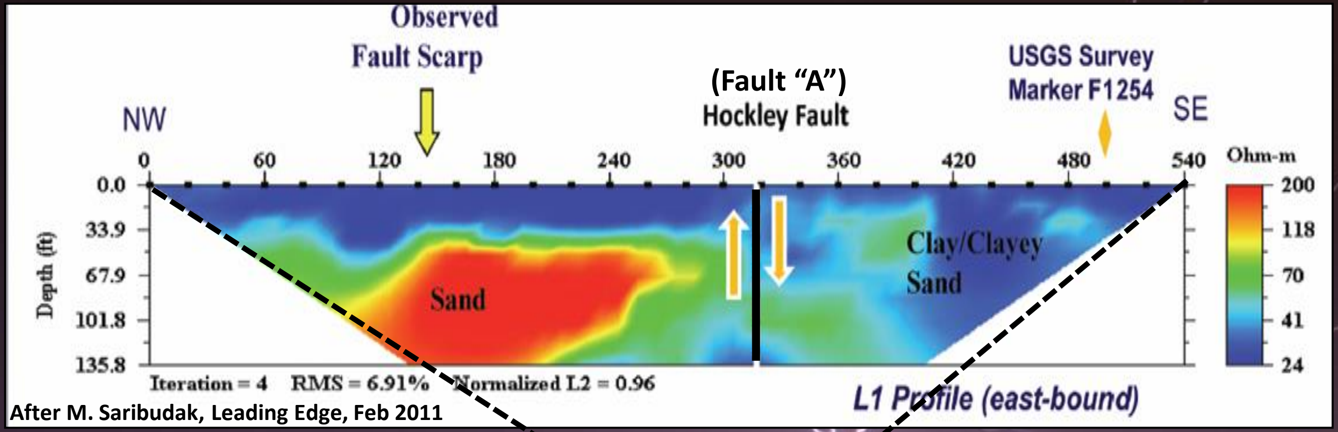
Line 2

NSEM 3-D Resistivity Profile

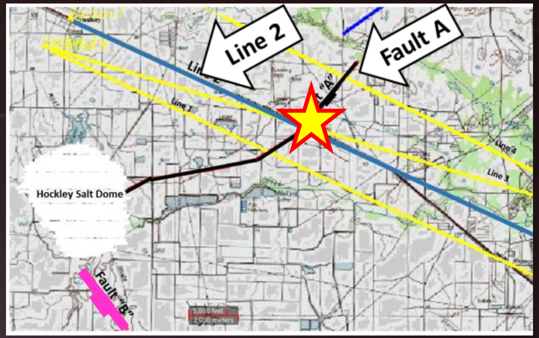


Sequence Stratigraphy & Buried Faults

See Lightning . . . DML . . . think DML & solutions



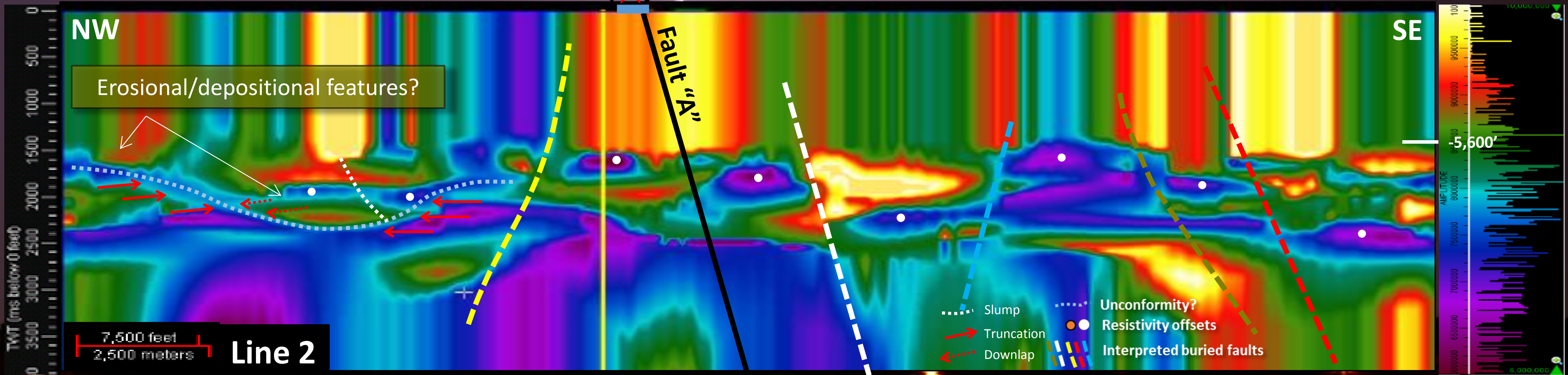
After M. Saribudak, Leading Edge, Feb 2011



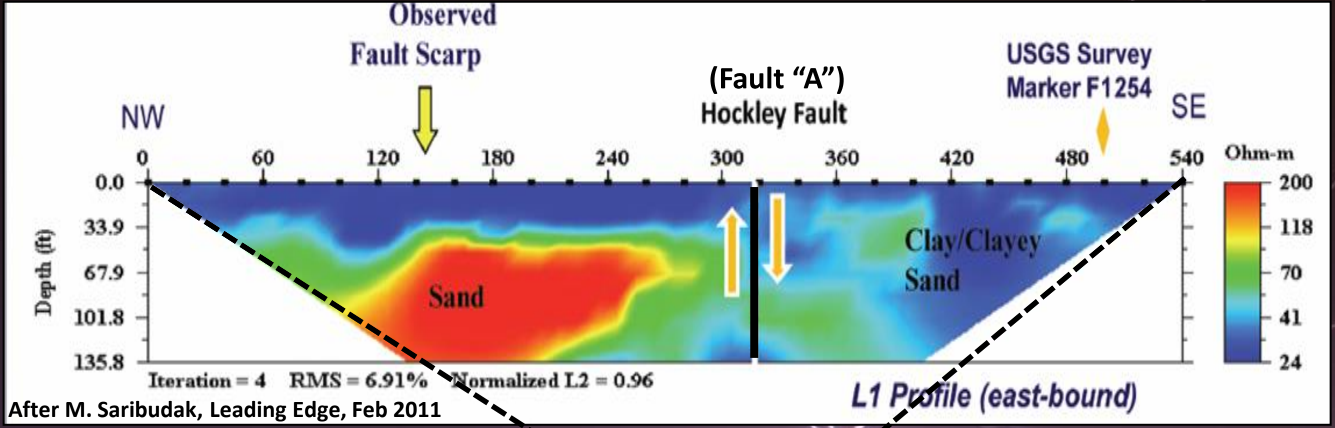
Line 2

Can NSEM map stratigraphy?

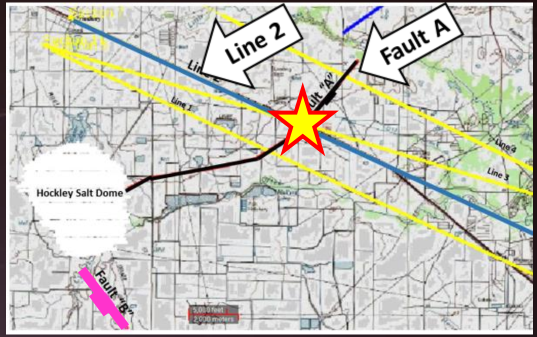
NSEM identifies "buried" faults.



Interpretive Ambiguity & 3-D Mapping



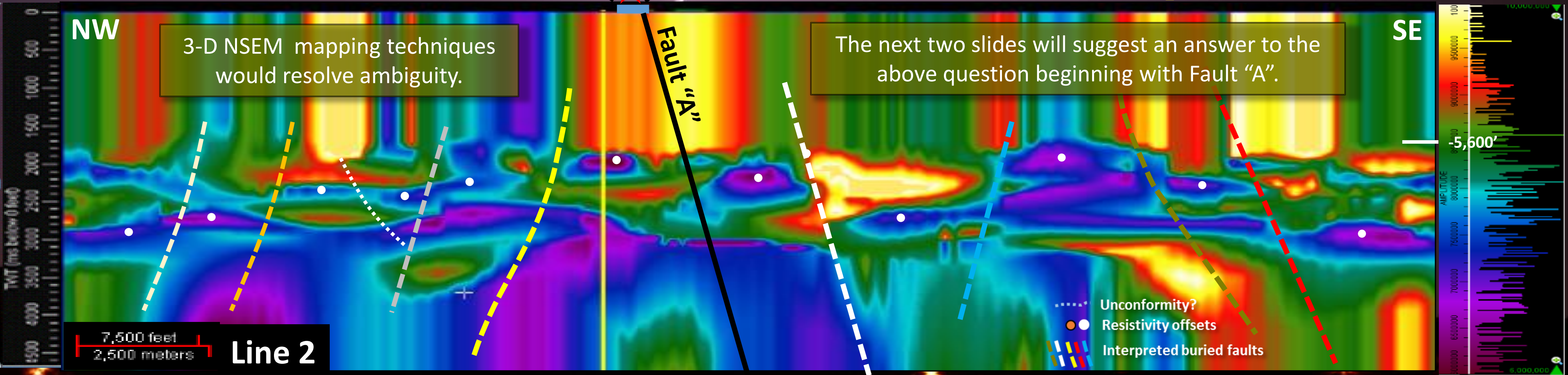
After M. Saribudak, Leading Edge, Feb 2011



Line 2

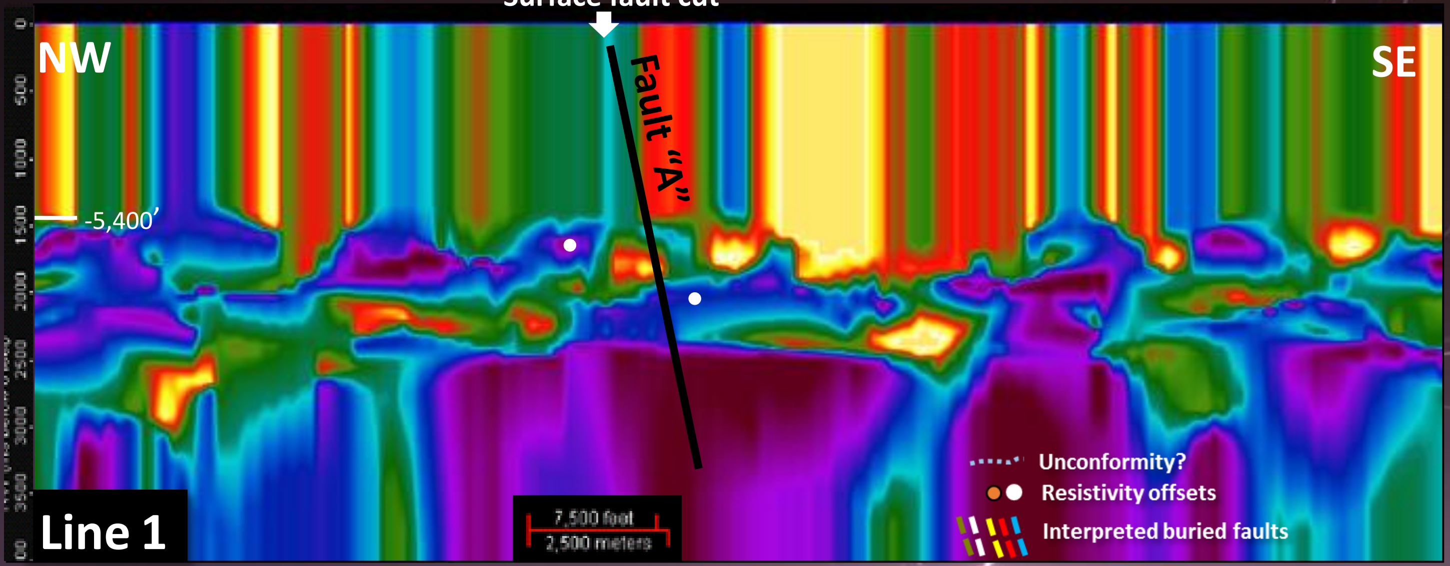
Alternate structural interpretation.

How reliable is this fault interpretation?

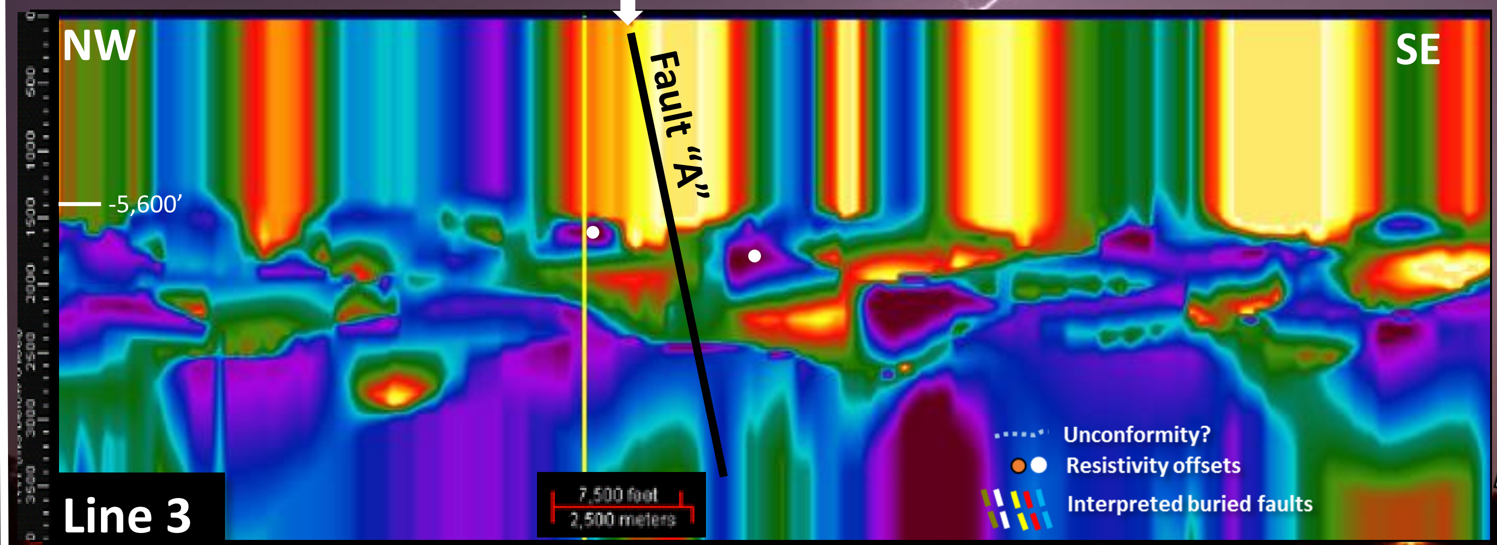


Multiple NSEM Lines Document Fault "A"

Surface fault cut



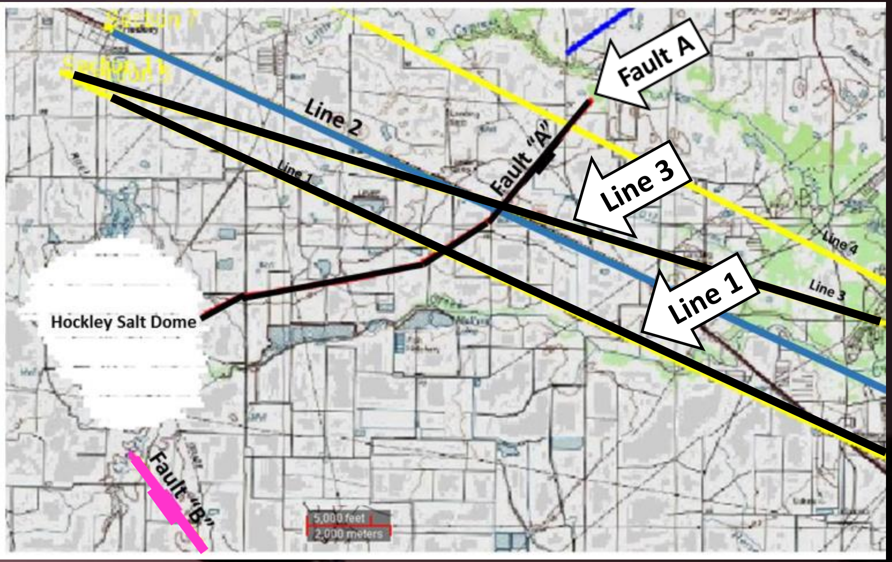
Line 1



Line 3

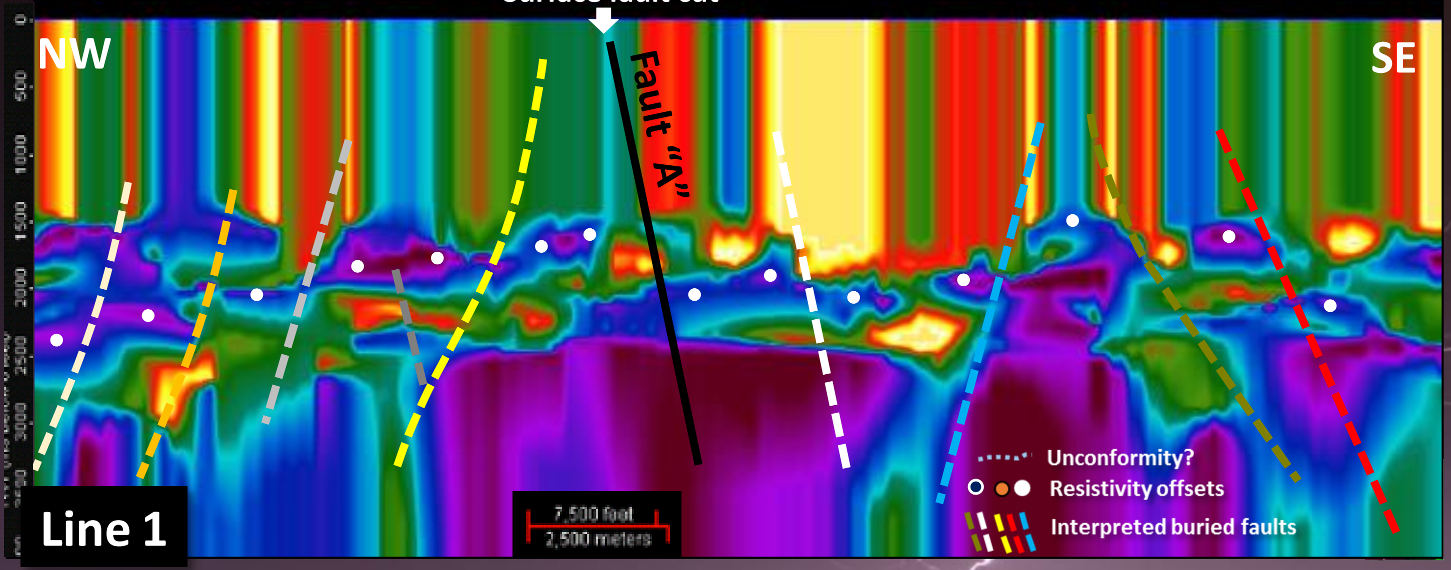
See Lightning . . .
DML
. . . think DML & solutions

NSEM Demonstrates Reliability & Consistency Picking Fault "A". Ties Surface Fault to Depth.

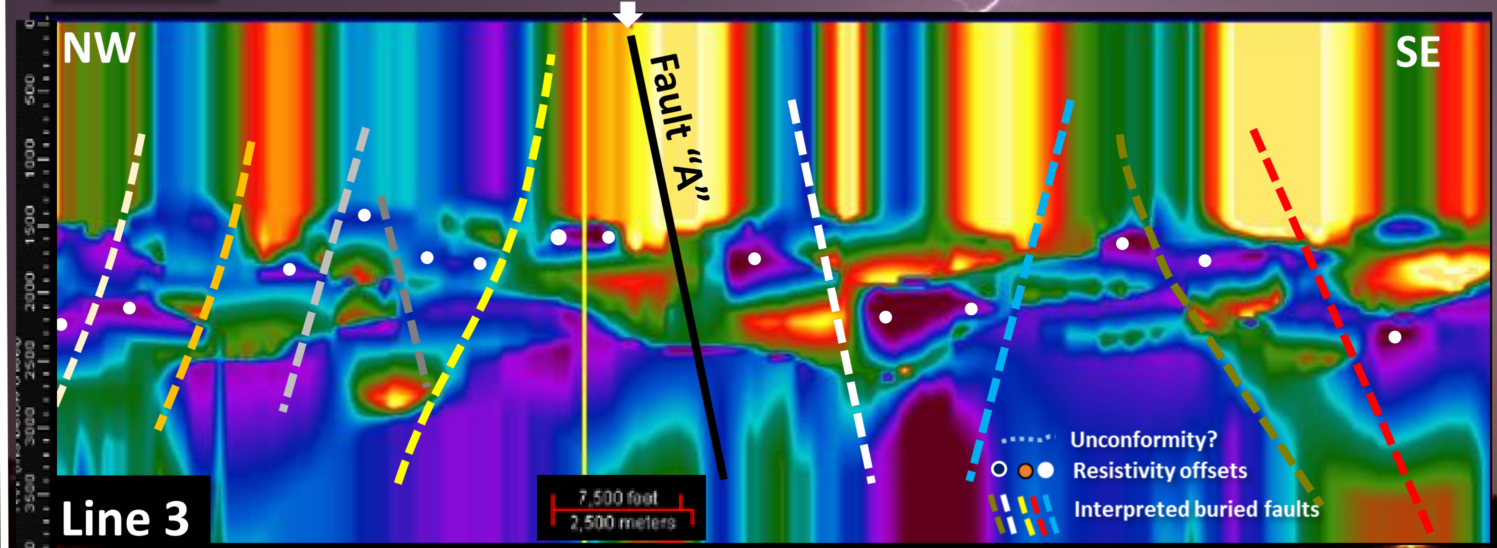


3-D NSEM Extends 2-D Resistivity

Surface fault cut

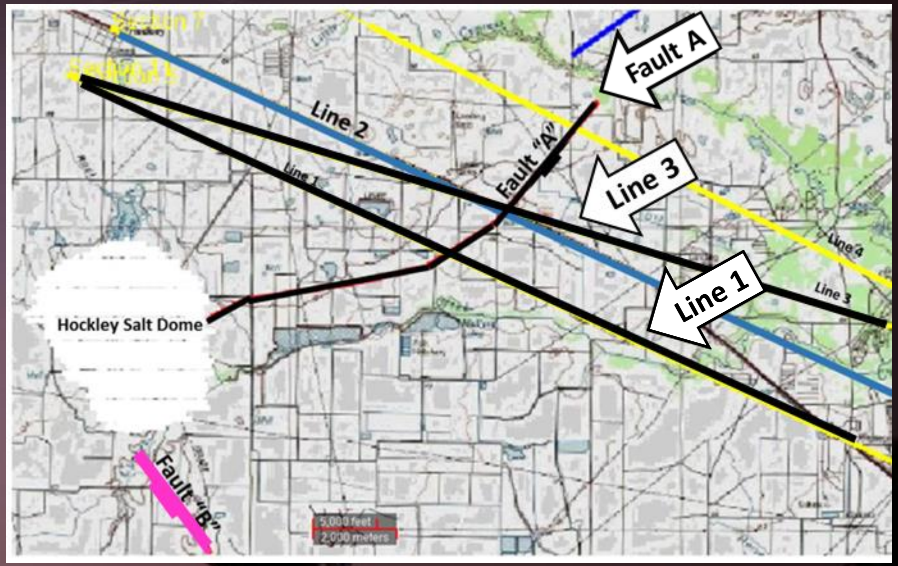


Line 1

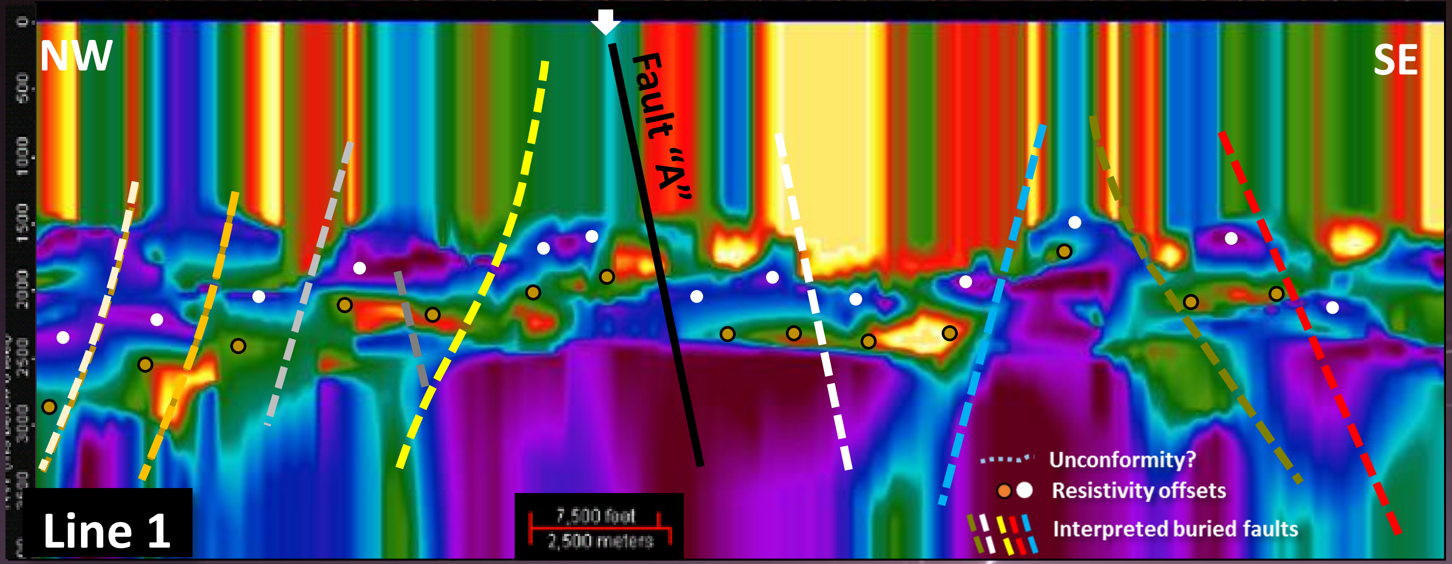


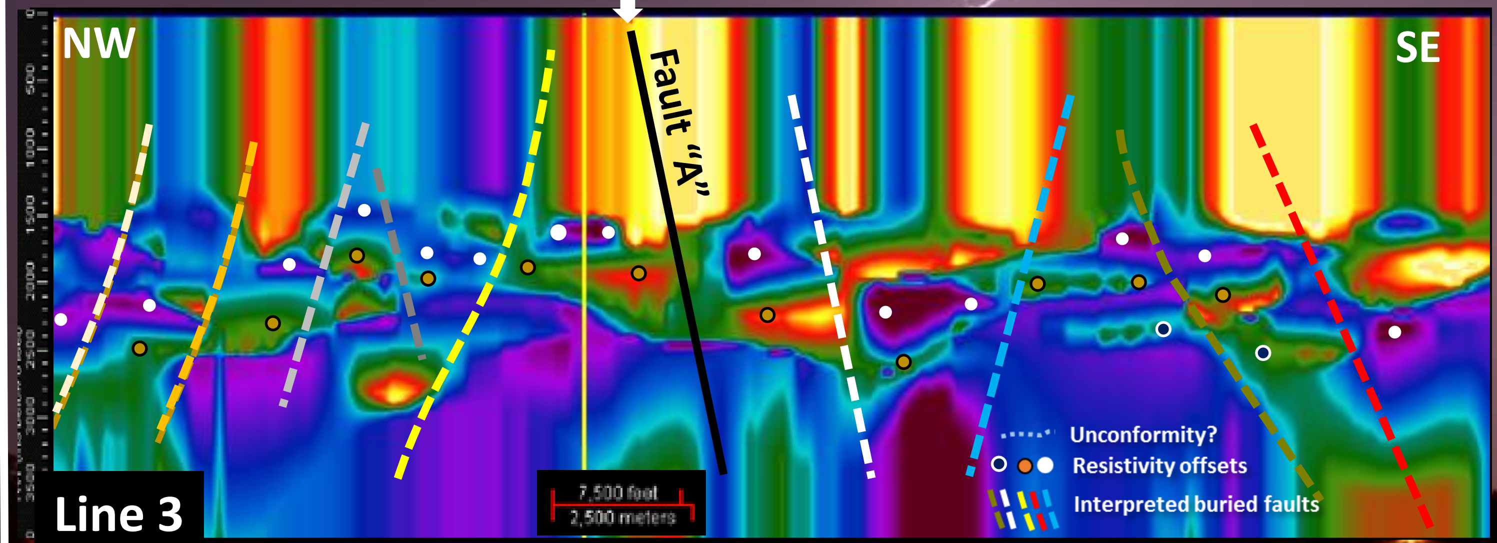
Line 3

NSEM Demonstrates Reliability & Consistency Mapping 9 Faults. Facilitates Mapping Fault Traces.



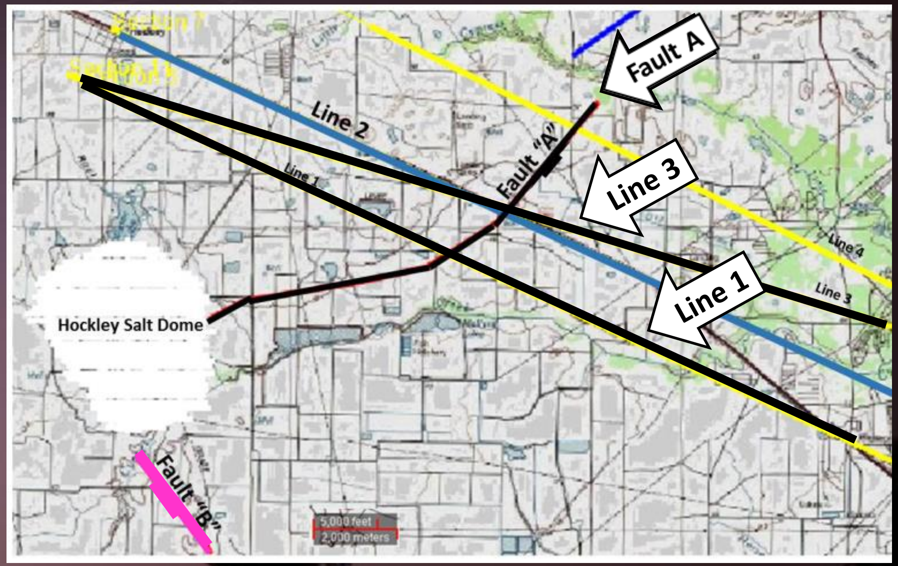
Calibrated NSEM
Builds Reliable Structural Framework





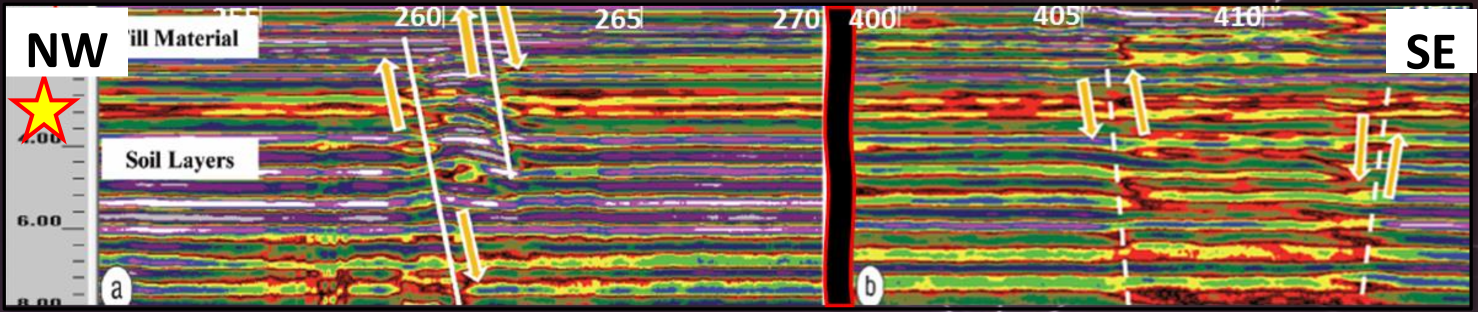
Multiple Resistivity Offsets.

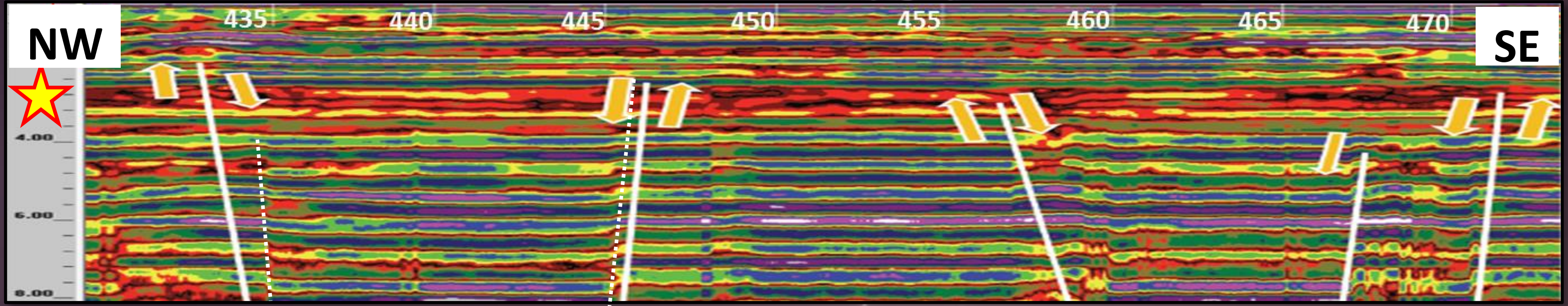
3-D NSEM Enables Fault Surface & Structural Mapping.

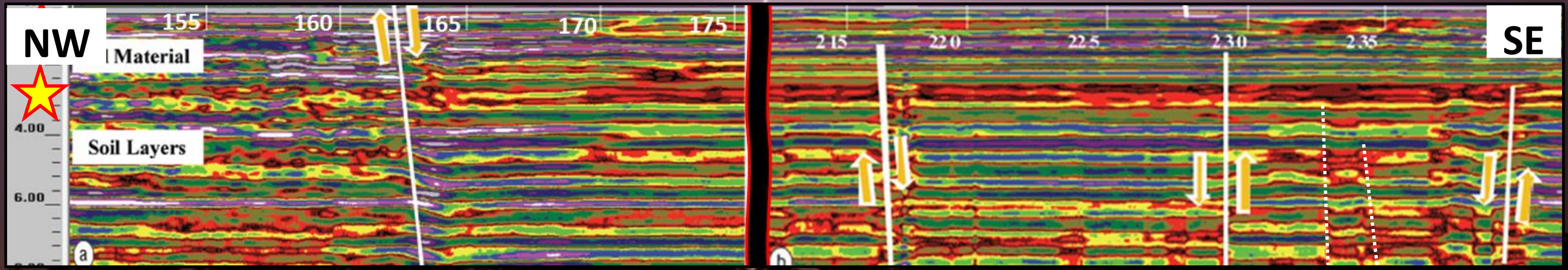


Ground Penetrating Radar

Shallow Micro-Faulting Adjacent to Fault “A”

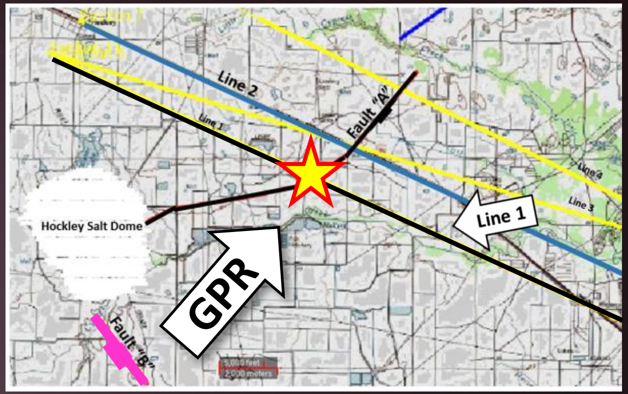






After M. Saribudak, Leading Edge, Feb 2011

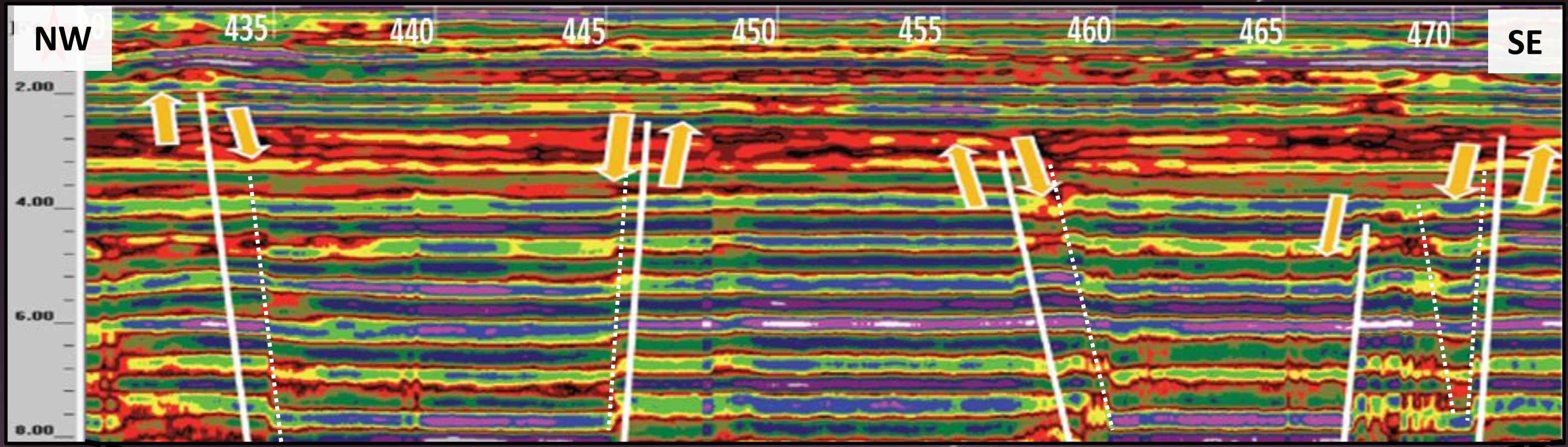
Reveals Fault Style Similar to NSEM Findings at Depth.



Faults added by this author to augment published interpretation & to correct slippage of original fault segment overlays.

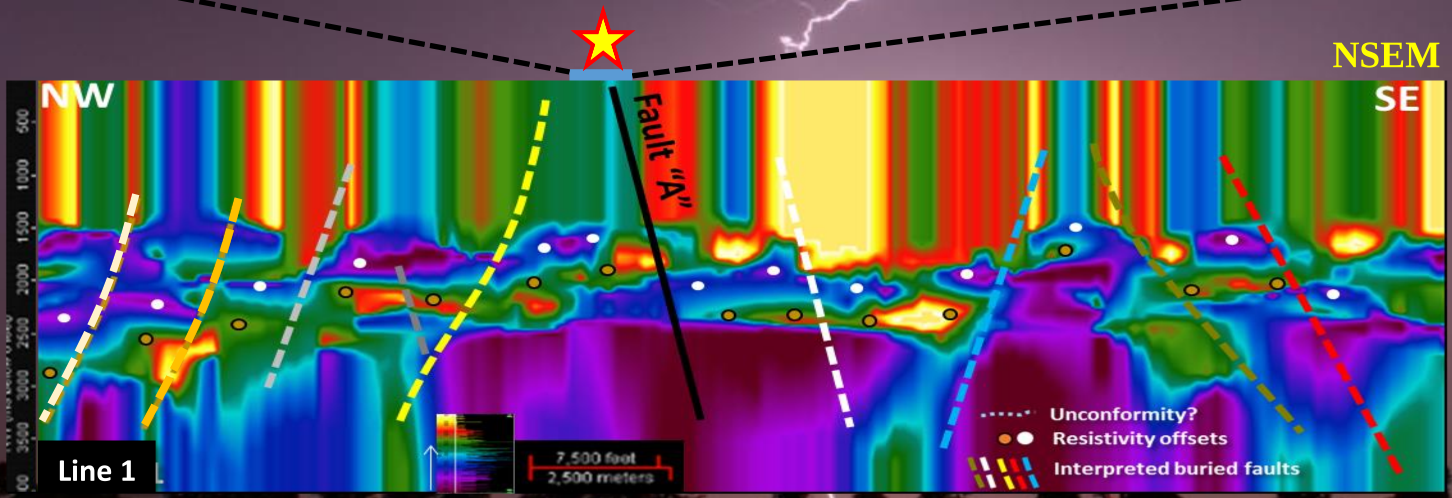
GPR & NSEM
Similar Micro/Macro Structural Styles

GPR



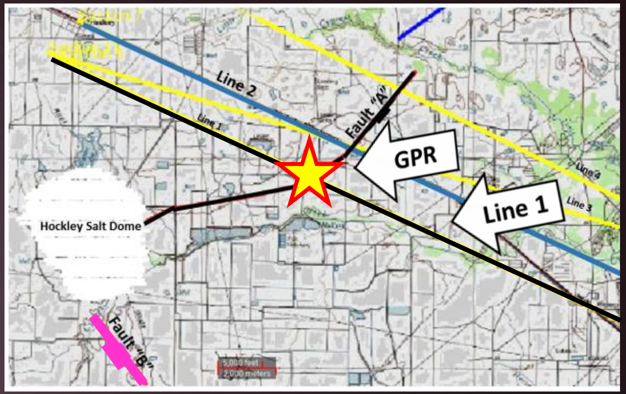
GPR

NSEM

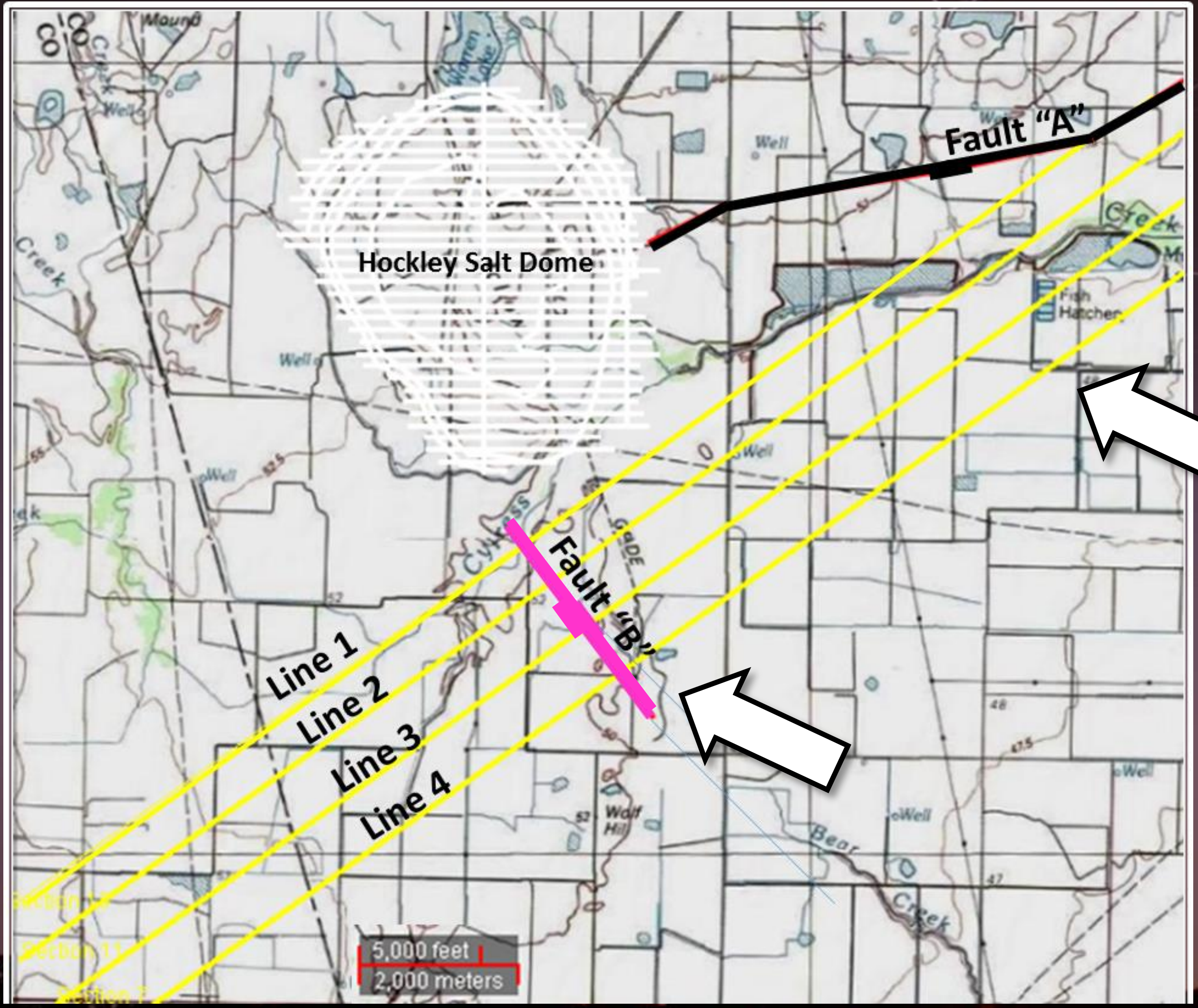


Line 1

Horsts, Grabens & Half-Graben Structures

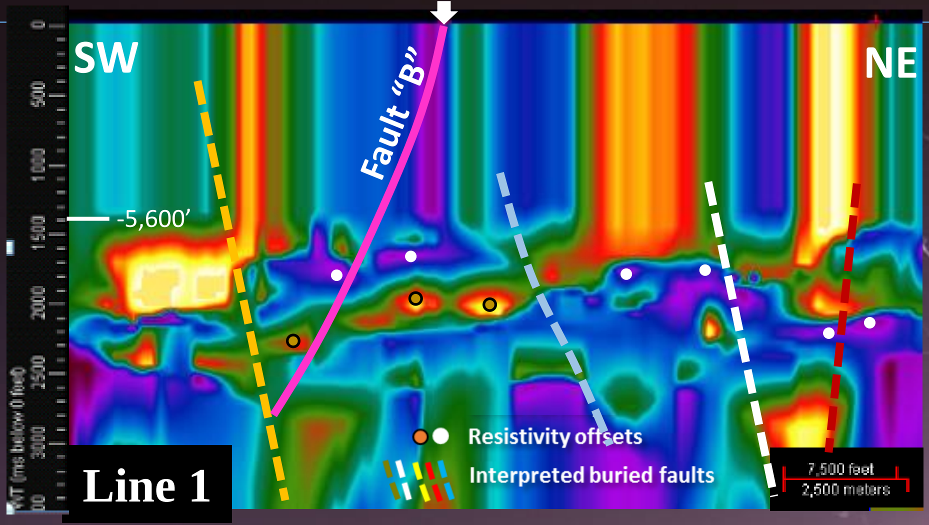


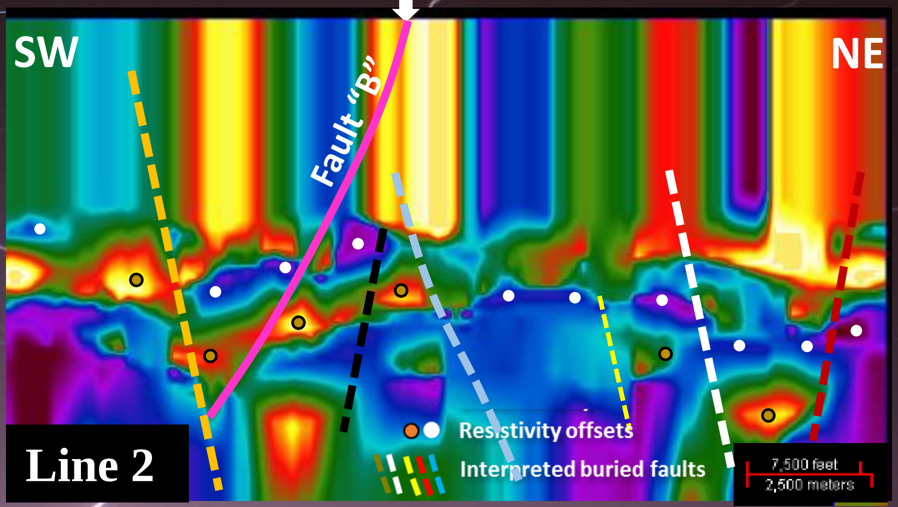
Hockley Radial Fault "B"

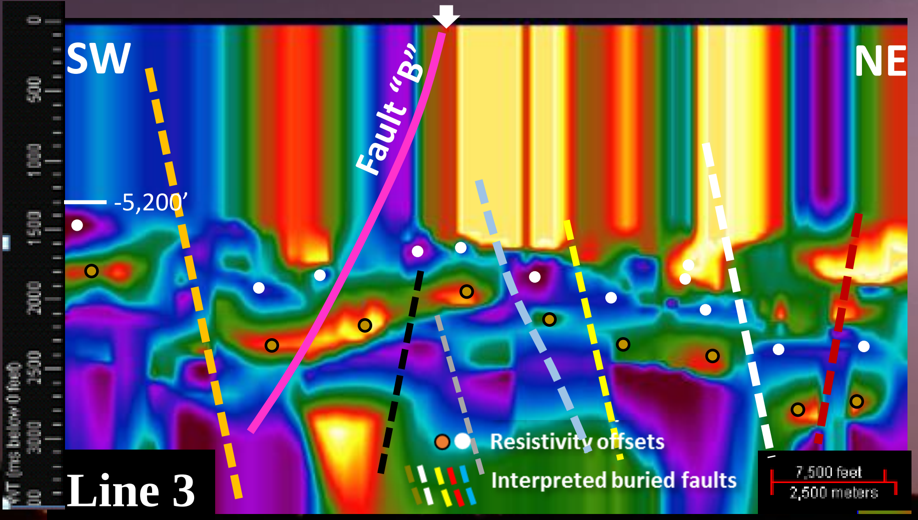


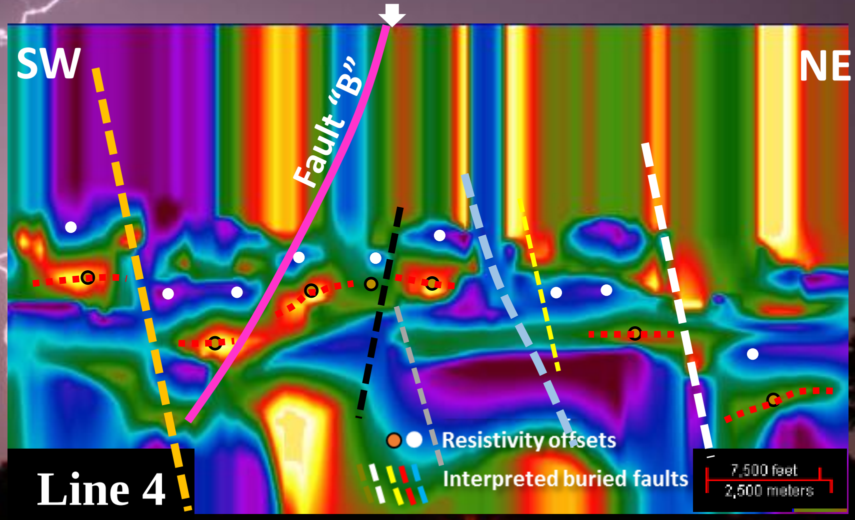
Resistivity profile Lines 1-4 displayed on next slide.

Hockley Radial Fault “B” Lines 1-4

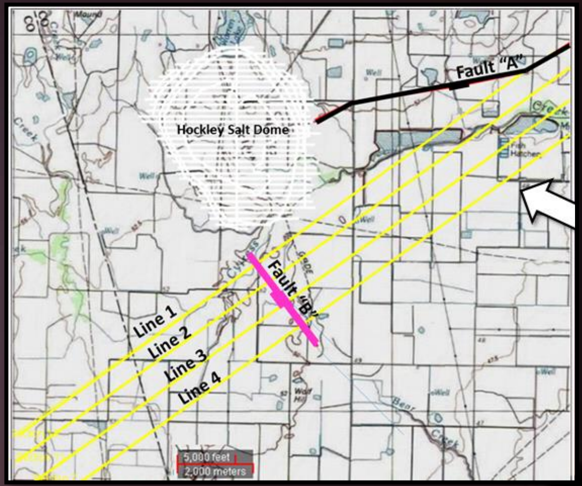


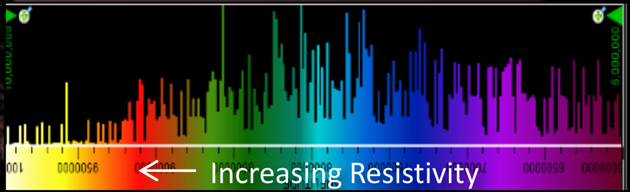




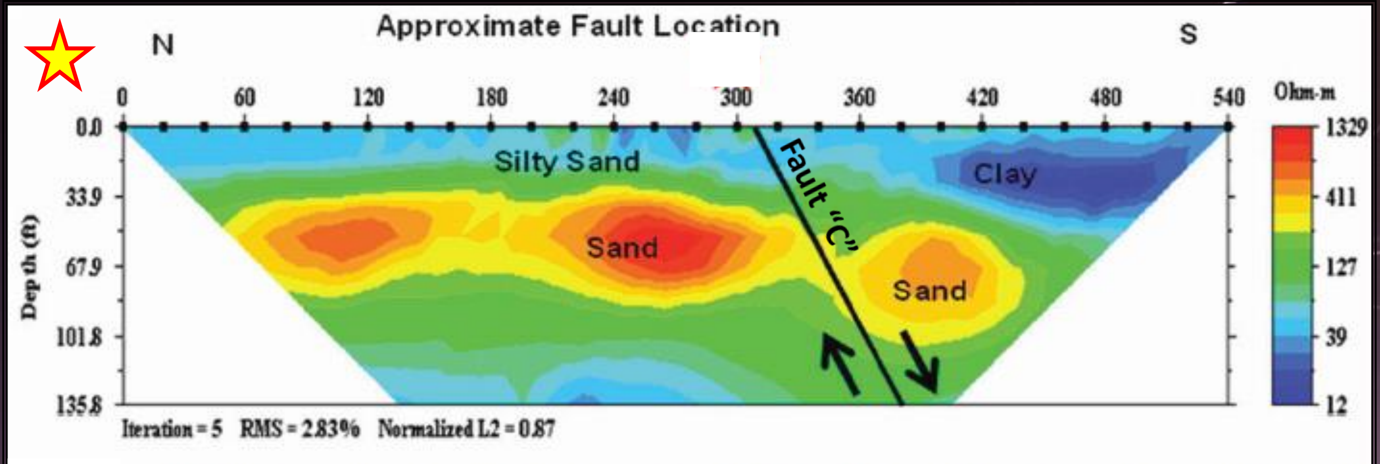


Consistency Tying Surface Fault & Picking As Many As Seven Faults.



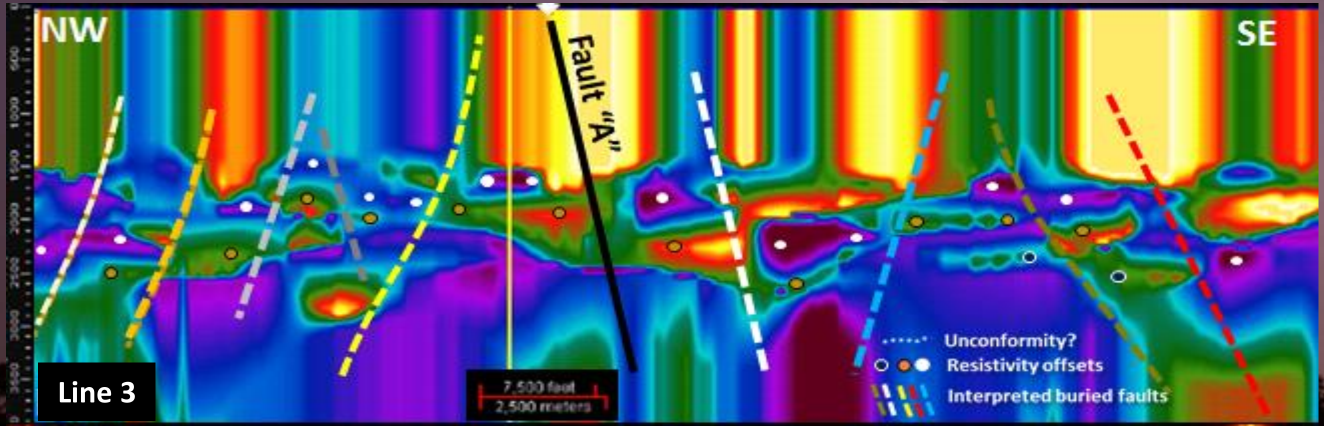


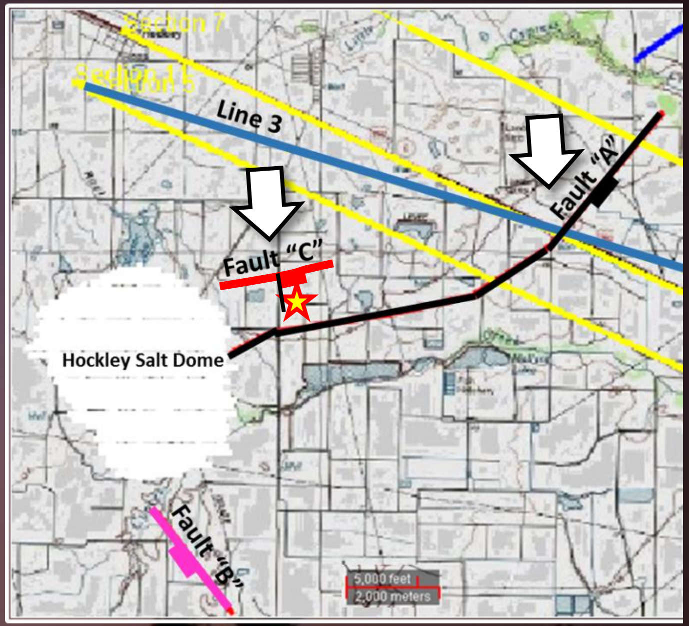
Hockley Radial Fault "C"
2-D Resistivity Imaging Fault Signature



Resistivity imaging data taken across the Katy-Hockley fault. Note the south-dipping sand layers and thickening clay layers in the downthrown side. After M. Saribudak, Fast Times, Vol 17, No. 1, March 2012

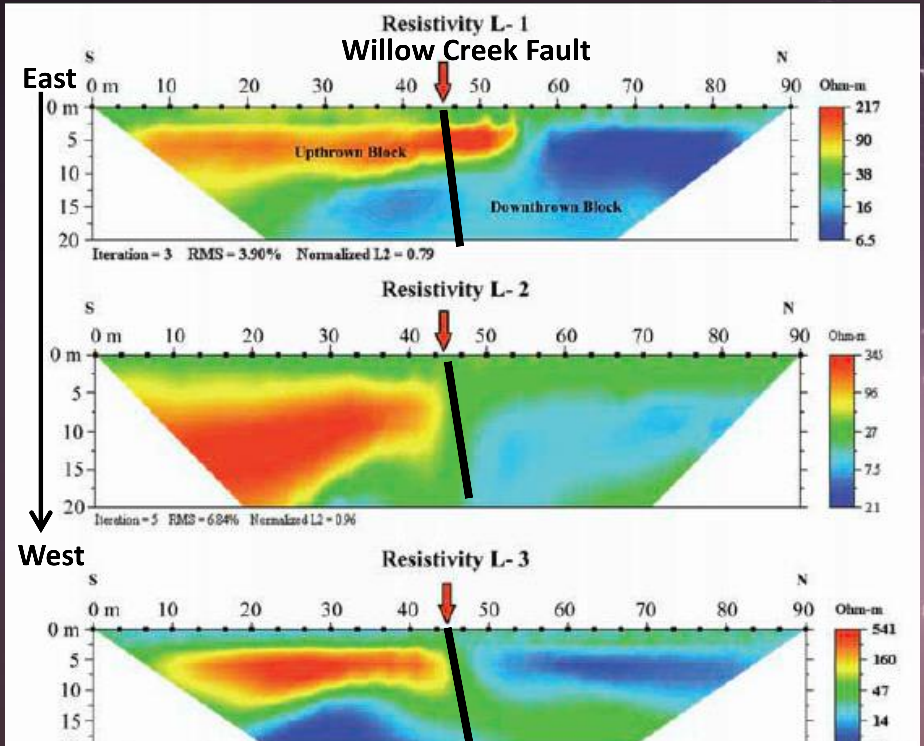
NSEM 3-D Resistivity Duplicates 2-D Resistivity Fault Signature.





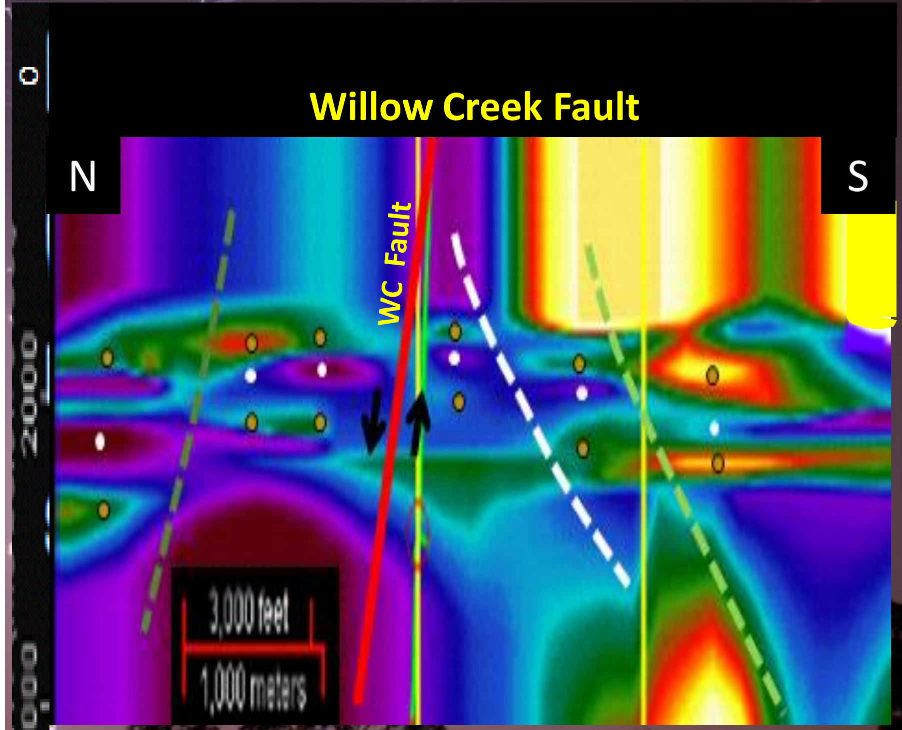
Willow Creek Fault, Tomball, TX
NSEM Duplicates Resistivity Fault Signature

2-D Resistivity Imaging

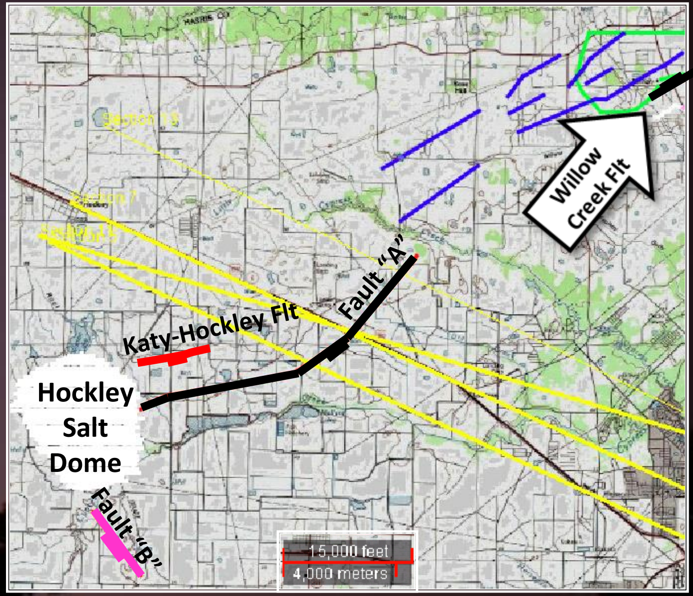


After M. Saribudak, "Integrated Geophysical Studies Over Active Growth Fault, Houston"; The Leading Edge, March 2006.

3-D NSEM



NSEM Again Ties Surface Fault



NSEM Overview

- NSEM resistivity volumes map shallow to deep targets, from about 2,700' to 15,000' depending on weathering & sub- weathering thickness, aggregate interval velocity & the area's average lightning peak charge.
- NSEM resistivity is displayed & interpreted in 3-D fashion & easily integrated with surface geology, well data, synthetic seismograms, seismic refraction, 2-D/3-D seismic reflection & potential field data.
- To date NSEM has been used to map faults, stratigraphy & rock properties & to identify hydrocarbon accumulations.
- At a minimum, NSEM is a cost effective reconnaissance tool that can be acquired, processed and interpreted for 1% of the cost of 3-D seismic data.

Dynamic Measurement, LLC.

See Lightning . . .
DML
. . . think DML & solutions

For questions regarding:

- Proprietary NSEM Sales
- Project Design
- Project Management
- NSEM & Geoscience Data Integration
- Seismic Interpretation
- Exploration, Exploitation or New Ventures

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